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Research
Paper NC-293

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Manuscript approved for publication July 11, 1990
1990

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The oak-hickory forest type is the most extensive deciduous type in the United States, and is regenerated primarily by clearcutting (Zeedyk and Evans 1975). Clearcutting small stands in oak-hickory forests is also recommended to create early successional forest and increase habitat diversity for some species such as white-tailed deer (*Odocoileus virginianus*) and ruffed grouse (*Bonasa umbellus*) (Evans 1974). Clearcut stands also provide habitat for many nongame birds, however the forest edge created by clearcutting may negatively affect some forest wildlife in adjacent mature stands (Wilcove 1988). Several studies have investigated nongame bird use of clearcut stands in oak-hickory forests (Conner and Adkisson 1975, Evans 1978, Probst 1979, Crawford *et al.* 1981, Horn 1984, Yahner 1986), but none have estimated breeding bird densities in small clearcut stands in the Midwest. Information is needed on breeding bird use of clearcut stands and older oak-hickory forests in the Midwest to evaluate the impact of even-aged forest management on nongame birds.

In this study we evaluated breeding bird use of small commercially clearcut areas within a large, contiguous forest. The areas were clearcut to meet timber and ruffed grouse management objectives. We determined breeding bird densities and diversity in small stands (1 to 4.5 ha) 1 year before and 3 years after clearcutting and in adjacent mature, undisturbed stands.

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STUDY AREA AND METHODS

This study was conducted on the 900-ha Ashland Wildlife Research Area (AWRA) in southern Boone County, Missouri. Elevation ranges from 170 m in narrow waterways to 244 m on rolling, narrow ridges with gentle to steep slopes. The area is primarily forested with upland oak-hickory and bottomland hardwoods but is interspersed with open areas and old fields. About 80 percent of the area within a 5-km radius of the study area is forested.

Birds were censused on two study sites; site A was 450 by 450 m (20.25 ha), and site B was 400 by 450 m (18 ha) (fig. 1). Both sites were mature oak-hickory forests before portions were clearcut during this study. Dominant overstory trees were white oak (*Quercus alba*), chinkapin oak (*Q. meuhlenbergii*), northern red oak (*Q. rubra*), black oak (*Q. velutina*), bitternut hickory (*Carya cordiformis*), mockernut hickory (*C. tomentosa*), and sugar maple (*Acer saccharum*). The understory was composed of sugar maple, downy serviceberry (*Amelanchier arborea*), hophornbeam (*Ostrya virginiana*), flowering dogwood (*Cornus florida*), and blackhaw viburnum (*Viburnum prunifolium*). Both sites were bisected by an intermittent stream that created breaks in the canopy.

A 4.5-ha stand was clearcut in the southwest corner of site A in fall 1982 and three stands (1.1, 1.4, and 2.0 ha) were clearcut in the western half of site B in summer 1984. Dominant vegetation in the clearcut stands 3 years after clearcutting was sugar maple, hophornbeam, downy serviceberry, northern red oak, white oak, and flowering dogwood in the form of stump sprouts, advanced reproduction, and larger

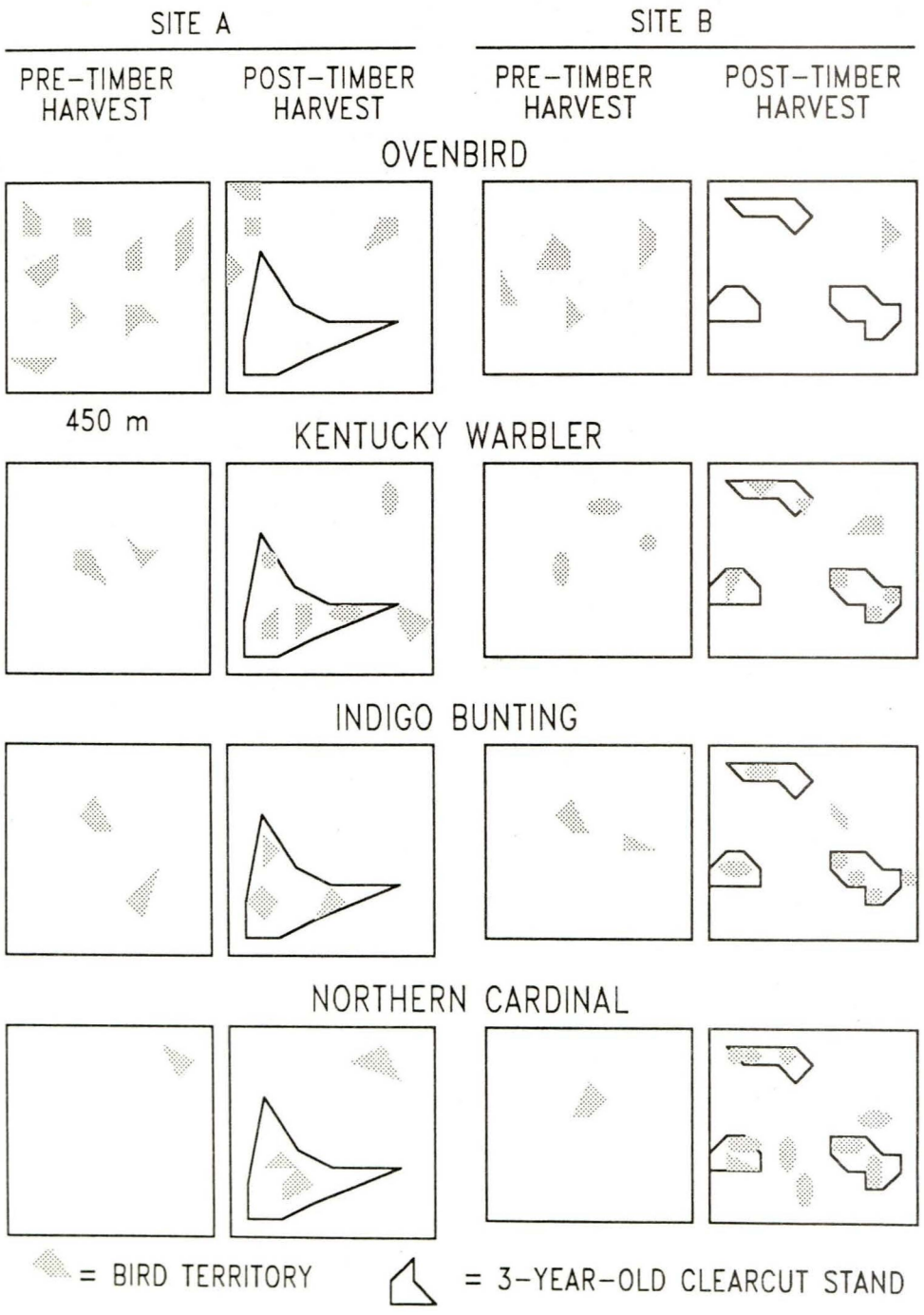

Figure 1.—*Locations of breeding territories of four bird species in a Missouri oak-hickory forest 1 year before and 3 years after portions were clearcut, 1982-1987.*

residual stems. Mean stem densities of woody vegetation, snag density, canopy height, and canopy closure in the clearcut and mature forest stands were calculated from forest inventory data (forest inventory data 1983 to 1987, on file AWRA) (table 1). High snag densities were created by girdling most of the residual stems after commercial timber harvest.

Table 1.—*Mean vegetation structure of 3-year-old clearcut and mature oak-hickory forest stands on two sites censused for breeding birds in Missouri*

Variable	3-year-old clearcut *n* = 4	Mature forest *n* = 2
Stems/ha <3 cm d.b.h.	10,413	7,578
Stems/ha 3-10 cm d.b.h.	9	578
Stems/ha 11-23 cm d.b.h.	13	390
Stems/ha >23 cm d.b.h.	25	209
Snags/ha[1]	98	37
Canopy height (m)	18.3	3.1
Canopy closure(%)	96	9

[1]Dead stems >10 cm d.b.h.

Birds were censused 1 year before and 3 years after clearcutting. Densities of territorial breeding birds were estimated by the territory mapping method (Williams 1936, Robbins 1978). All censusing was conducted by F. R. Thompson from 0600-1000 hours, 23 May to 3 July. North-south transects were placed 50-m apart and points were labeled at 50-m intervals along each transect. Bird observations were mapped along the transects during 10 to 11 trips to each site. Each trip began at a different point and covered all transects. Site A was censused in 1982 and 1985, site B was censused in 1984 and 1987. Because of the large number of species observed and low number of treatment replications (two study plots with four clearcuts), we only present descriptive statistics. Mean bird densities were calculated for site A and B before clearcutting and for the forested portions of site A and B after clearcutting. Mean bird densities in clearcut stands were calculated from the one clearcut stand on site A and three clearcut stands on site B (table 2). Species diversity (H') and equitability (J') were calculated with the Shannon diversity index (Hair 1980) (table 3).

In addition to clearcutting, other factors could have caused fluctuations in bird densities between years. We examined regional changes in bird densities among the years of this study to assess this potential source of variation. We selected seven breeding bird survey routes (U.S. Fish and Wildlife Service Breeding Bird Survey Files, Laurel, MD) located in primarily forested habitat within a 62-km radius of our study area. For each species and year of this study, we tallied the number of individuals observed per route. We used Kruskal-Wallis tests (SAS Institute 1985: 607) to test the hypothesis that species abundances (observed individuals/route) were the same in 1982, 1984, 1985, and 1987. We were unable to reject this hypothesis for any species in this study ($P \leq 0.05$). Although the power of this test was probably small, it suggests that no large regional changes in species populations occurred during the years of this study, so populations before and after clearcutting can be compared.

RESULTS

We observed 45 bird species and were able to map territories of 27 species in the mature forest stands and 17 species in the clearcut stands (table 2). We were unable to determine the density of some species because their territories were larger than census sites (e.g., pileated woodpecker [*Dryocopus pileatus*]), individuals were in groups (e.g., brown-headed cowbird [*Molothus ater*]), or we had less than three observations (e.g., white-eyed vireo [*Vireo griseus*]).

Northern cardinals, Kentucky warblers, indigo buntings, rufous-sided towhees, yellow-breasted chats, and blue-winged warblers (scientific names in table 2) occurred at high densities in the 3-year-old clearcut stands. Before clearcutting, indigo buntings and northern cardinals bred at low densities along edges and canopy breaks associated with intermittent streams. Yellow-breasted chats, blue-winged warblers, rufous-sided towhees, field sparrows, and American goldfinches bred only in clearcut stands (table 2, fig. 1). Ovenbirds, worm-eating warblers, great-crested flycatchers, blue jays, Kentucky warblers, and tufted titmice were the most abundant breeding birds prior to clearcutting and in the mature forest portion of the study sites after clearcutting, though total numbers of ovenbirds and worm-eating warblers declined

Table 2.—*Mean density of breeding birds in oak-hickory forest before and after clearcutting in Missouri, 1982-87*

Species	Density (territories/10 ha) Pre-harvest Forest	3-years post-harvest Forest	3-years post-harvest Clearcut
Mourning dove *(Zenaida macroura)*	0.3 (0.25)[1]	0.7 (0.05)	0.0 (0.00)
Yellow-billed cuckoo *(Coccyzus americanus)*	1.1 (0.06)	0.7 (0.05)	0.0 (0.00)
Whip-poor-will *(Caprimulgus vociferus)*	0.3 (0.28)	0.7 (0.05)	0.0 (0.00)
Red-bellied woodpecker *(Melanerpes carolinus)*	0.8 (0.22)	0.4 (0.37)	0.6 (0.56)
Downy woodpecker *(Picoides pubescens)*	0.3 (0.28)	0.0 (0.00)	1.8 (1.19)
Hairy woodpecker *(Picoides villosus)*	0.3 (0.28)	0.7 (0.05)	0.0 (0.00)
Eastern wood-pewee *(Contopus virens)*	0.7 (0.74)	1.7 (0.21)	0.6 (0.56)
Acadian flycatcher *(Empidonax virescens)*	0.0 (0.00)	0.4 (0.37)	0.0 (0.00)
Eastern phoebe *(Sayornis phoebe)*	0.0 (0.00)	0.7 (0.74)	0.0 (0.00)
Great-crested flycatcher *(Myiarchus crinitus)*	1.6 (0.09)	1.1 (0.42)	2.4 (1.37)
Blue jay *(Cyanocitta cristata)*	1.1 (0.06)	2.1 (0.16)	0.0 (0.00)
Black-capped chickadee *(Parus atricapillus)*	0.3 (0.28)	0.4 (0.37)	0.6 (0.56)
Tufted titmouse *(Parus bicolor)*	1.3 (0.19)	2.8 (0.90)	0.0 (0.00)
White breasted nuthatch *(Sitta carolinensis)*	1.0 (0.46)	1.8 (0.48)	0.6 (0.56)
Carolina wren *(Thryothorus ludovicianus)*	0.0 (0.00)	0.4 (0.37)	1.3 (1.25)
Blue-gray gnatcatcher *(Polioptila caerulea)*	0.3 (0.28)	0.0 (0.00)	1.3 (1.25)
Wood thrush *(Hylocichia mustelina)*	1.0 (0.46)	0.6 (0.63)	0.0 (0.00)
Red-eyed vireo *(Vireo olivaceus)*	1.0 (0.46)	0.7 (0.05)	0.0 (0.00)
Blue-winged warbler *(Vermivora peregrina)*	0.0 (0.00)	0.0 (0.00)	3.0 (1.81)
Northern parula *(Parula americana)*	0.3 (0.28)	0.7 (0.74)	0.0 (0.00)
Black-and-white warbler *(Mniotilta varia)*	1.3 (0.19)	1.4 (0.79)	0.6 (0.56)
Worm-eating warbler *(Helmintheros vermivorus)*	2.4 (0.12)	2.4 (0.53)	0.0 (0.00)
Louisiana waterthrush *(Seirus motacilla)*	1.1 (0.06)	1.0 (0.26)	0.0 (0.00)
Ovenbird *(Seiurus aurocapillus)*	3.1 (0.86)	1.6 (0.90)	0.0 (0.00)
Kentucky warbler *(Oporornis formosus)*	1.6 (0.62)	1.0 (0.26)	11.8 (1.64)
Yellow-breasted chat *(Icteria virens)*	0.0 (0.00)	0.0 (0.00)	5.9 (1.47)
Summer tanager *(Piranga rubra)*	0.3 (0.28)	0.7 (0.05)	0.0 (0.00)
Scarlet tanager *(Piranga olivacea)*	0.3 (0.28)	1.1 (0.42)	0.0 (0.00)
Northern cardinal *(Cardinalis cardinalis)*	0.5 (0.03)	1.4 (0.79)	13.5 (3.86)
Indigo bunting *(Passerina cyanea)*	1.1 (0.06)	0.7 (0.74)	9.5 (1.91)
Rufous-sided towhee *(Pipilo erythrophthalmus)*	0.0 (0.00)	0.0 (0.00)	9.3 (3.01)
Field sparrow *(Spizella breweri)*	0.0 (0.00)	0.0 (0.00)	2.3 (2.27)
American goldfinch *(Carduelis tristis)*	0.0 (0.00)	0.0 (0.00)	2.3 (2.27)

[1]Numbers in parentheses are the standard errors, and should be interpreted with caution due to small sample sizes (mature forest, n=2; clearcut stands, n=4).

following clearcutting due to a loss of mature forest within each study site (table 2, fig. 1). Mean number of species breeding and mean species diversity appeared greater in the mature forest, and mean total bird density appeared greater in the clearcuts (table 3). Mean species equitability and number of species observed were similar (table 3).

DISCUSSION

Species breeding in mature forest stands in this study were common in mature oak-hickory forest in the Missouri Ozarks (Evans 1978), and bird densities were similar to those reported by Shugart *et al.* (1978) for mature eastern deciduous forest. Most birds we observed breeding in clearcut stands were common from 1 to 12 years after clearcutting in mixed oak stands in Virginia (Conner and Adkisson 1975) and Missouri (Evans 1978).

Table 3.—*Mean avian diversity and total breeding bird density (territories/10 ha) in oak-hickory forest before and after clearcutting in Missouri, 1982-1987*

Variable	Pre-harvest Forest	3-years post-harvest Forest	3-years post-harvest Clearcut
Number of species observed	26 (2.8)[1]	27 (3.0)	23 (1.9)
Number of species breeding	22 (3.5)	24 (3.5)	8 (1.3)
Species diversity[1]	2.9 (0.16)	3.0 (0.13)	2.0 (0.15)
Species equitability[2]	0.95 (0.001)	0.94 (0.002)	0.92 (0.004)
Total density	23.8 (0.43)	29.6 (6.72)	66.9 (7.66)

[1]Numbers in parentheses are the standard errors.

Total bird density was nearly two times greater in clearcuts than in mature forest. In Pennsylvania, Yahner (1986) reported only slightly greater bird densities in 5- to 8-year-old oak clearcut stands than in mature oak forest; bird densities in clearcuts were less than, and densities in forests greater than detected in this study. Also in Pennsylvania, Probst (1979) reported bird densities for clearcuts that were similar to those found in this study, but he reported densities for mature forest that were greater than those found in this study.

We detected more territorial-breeding species in mature forest than clearcut stands. The mean number of species breeding in clearcut stands was much lower than the total number breeding in all clearcut stands because not all stands contained every species. Similar to this study, Horn (1984) reported a mean of 8 and a total of 19 species breeding in 1- to 5-year-old clearcut stands in North Carolina.

Mean species diversity in clearcuts and mature forest was similar to that in mixed oak clearcuts and forests in Virginia (Conner and Adkisson 1975) but greater than that in Pennsylvania (Yahner 1986). Greater bird diversity in mature forest was due to a greater number of species and not greater equitability. Lower species richness and diversity in clearcuts was partly the result of the small size of the cuts (Connor and McCoy 1979) and partly the result of less vertical habitat structure (MacArthur and MacArthur 1961, Willson 1974) following the removal of most of the canopy and subcanopy.

Several area-sensitive forest birds bred in clearcut stands even though stands were <5 ha and only 3 years old. Blue-gray gnatcatchers, black and white warblers, and Kentucky warblers had similar or greater breeding densities in clearcut stands than in mature forest. However, even though clearcut stands were small, they were part of a large, contiguous, forested area (>1,000 ha). Whitcomb *et al.* (1981) also found area-sensitive species breeding in early successional forest if sufficiently large areas were available.

MANAGEMENT IMPLICATIONS

The objective of regulated even-aged management is to maintain a balanced distribution of forest age classes over time to provide a sustained yield of timber and constant availability of different habitats for wildlife (Zeedyk and Evans 1975). Limited clearcutting in extensively forested areas to maintain a balanced forest age class distribution would increase forest- or beta-level species diversity and total bird density. Although clearcut stands had lower species diversity (alpha level diversity) than the mature forest, they provided habitat for a group of early successional birds that were previously absent or limited to a few, naturally occurring canopy breaks.

Clearcutting reduces the amount of mature forest present and creates edges between early successional and older forest age classes. Reduction in the reproductive success of some forest interior birds has been associated with forest edges (Gates and Gysel 1978, Ambuel and Temple 1983, Wilcove 1985) and may be a factor causing regional declines in these species. In large forested areas managed for multiple-use, the edges created by clearcutting under regulated even-aged management may be tolerable. Breeding populations of three forest interior birds (ovenbirds, worm-eating warblers, and Kentucky warblers) on our study area are large enough to be viable (Wenny 1989), and these species are abundant throughout portions of the Mark Twain National Forest under even-aged management for nearly 20 years (F. Thompson, unpublished data).

These data should be interpreted cautiously because a species may be present in an area, even though reproductive success is poor, if the population is supported by immigration (Wilcove 1988). However, these areas are some of the least fragmented in the state and are more likely serving as sources of immigrants than population sinks. In more fragmented landscapes, edges created by timber harvest and forest fragmentation may suppress local populations of some forest interior birds. Research relating the population dynamics of forest birds to forest managment practices in landscapes exhibiting a range of forest fragmentation is needed to better understand management effects on these species.

Acknowledgments

We appreciate the assistance of M. R. Ryan, P. K. McDowell, D. G. Kusmec, and T. A. Aemisegger. Financial support for this study was provided by the Ruffed Grouse Society and the Missouri Department of Conservation. This is a contribution of the Missouri Cooperative Fish and Wildlife Research Unit (U. S. Fish and Wildlife Service, Missouri Department of Conservation, University of Missouri-Columbia, and Wildlife Management Institute, cooperating) and Journal Paper 11,003 of the Missouri Agricultural Experiment Station Project 189.

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Thompson, Frank R., III; Fritzell, Erik, K.
1990. **Bird densities and diversity in clearcut and mature oak-hickory forest.** Res. Pap. NC-293. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

Describes nongame bird densities and diversity in a central Missouri oak-hickory forest 1 year before and 3 years after portions were clearcut. Discusses changes in species density and diversity and their management implications.

KEY WORDS: Breeding birds, clearcutting, diversity, Missouri, oak-hickory forest, population densities.

Our job at the North Central Forest Experiment Station is creating, evaluating, and disseminating information and technology to improve management and use of our natural resources.

As a new generation of forests emerges in our region, managers are confronted with two unique challenges: (1) Dealing with the great diversity in composition, quality, and ownership of the forests, and (2) Reconciling the conflicting demands of the people who use them. Helping the forest manager meet these challenges while protecting the environment is what research at North Central is all about.

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☆U.S. GOVERNMENT PRINTING OFFICE: 1990 - 757-210/20025